The impact of climate change on electricity generation and demand profiles in Europe until 2100

Franziska Schöniger[1], Gustav Resch[2], Demet Suna[2], Florian Hasengst[1], Nicolas Pardo-Garcia[2], Gerhard Totschnig[2], Peter Widhalm[2], Herbert Formayer[3], Philipp Maier[3], David Leidinger[3], Imran Nadeem[4]

1. Energy Economics Group (EEG), TU Wien, Vienna, Austria

2. AIT Austrian Institute Of Technology, Vienna, Austria

3. Institute of Meteorology and Climatology, University of Natural Resources and Life Sciences, Vienna, Austria

4. International Water Management Institute (IWMI), Lahore, Pakistan

Objective & background

Climate change and decarbonization increase the risks for electricity system planning and operation due to extreme weather events. This raises the need for an accurate depiction of the impact of climate change on future energy systems and deeper collaboration between climatology and energy system modelling. In this work, we use current climate models to build a consistent data set for the future electricity generation and demand components in Europe which serve as inputs for energy system models. The set includes hydropower generation (run-of-river (RoR) and reservoir), which is underrepresented in the existing literature.

Method

The method combines climate and energy modelling and analyses an RCP4.5 and an RCP8.5 scenario [1]. Parameters like temperature, wind speed, radiation, and precipitation are processed to derive weather-dependent electricity generation and demand profiles in hourly resolution for Europe until 2100. On the electricity generation side, technology-specific processing steps are conducted to generate electricity generation profiles from climate data, e.g. the combination of wind speed levels with power curves of turbines. The following weather-dependent generation and demand profiles are generated (encompassing NUTS3-NUTS0 level):

- E-heating, e-cooling, and e-mobility charging demand (dependent on temperature)
- PV generation (dependent on radiation, losses dependent on temperature)
- Wind generation (dependent on wind speed)
- Hydro RoR and reservoir generation (dependent on hydro inflow)

Climate stress events in the electricity system are characterized by high demand and low renewable generation, often caused by compound effects. We define indicators for stress events in the electricity system (e.g., duration and severity of heat waves or dark doldrums) based on literature. A systematic assessment of the frequency and severity of those stress events, their development over time in the different climate scenarios, and regional and technology-specific differences is done.

Principal findings and conclusion

From the processed climate data, we receive hourly profiles for electricity demand and supply for all European countries, which can be analyzed individually or as connected regions. Figure 1 shows, as an example, Germany's distribution of the annual wind, PV, and hydro RoR generation, and the electricity demand for e-cooling and e-heating in the 30 weather years around 2050 and 2085 in the analyzed RCP4.5 and RCP8.5 scenarios in a reference electricity system.

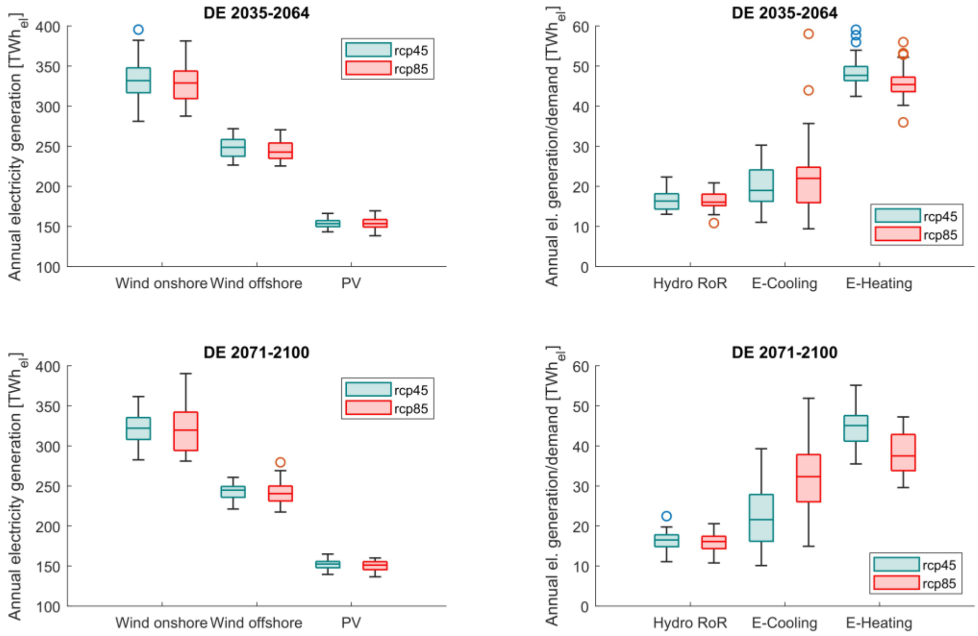

Figure 1: Annual wind, PV, and RoR generation, and electric cooling and heating demand in the 30 weather years surrounding 2050 and 2085 in the analyzed RCP4.5 and RCP8.5 scenario for Germany

In the German example, variations in the generation components are smaller than in the demand components. An increase in cooling and a decrease in heating demand can be observed over time. This will modify the seasonal timing of climate stress events. The standard deviation is higher in RCP8.5 than RCP4.5 and increases over time for most components.

The climate and energy data sets for the whole of Europe in hourly resolution until 2100 have been generated in the course of the project SECURES and will be made accessible open-source.

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[1] CORDEX-EUR-11-ICHEC-EC-EARTH-rcp45/rcp85-r12i1p1-KNMI-RACMO22E-v1